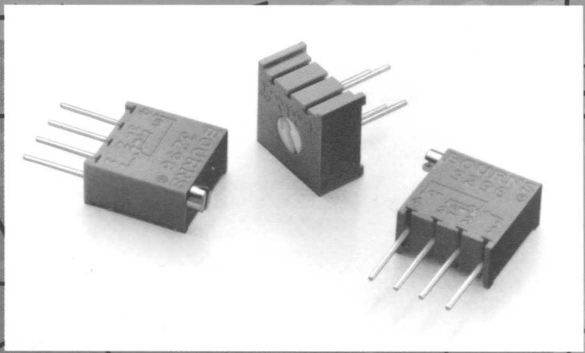
BOURNS



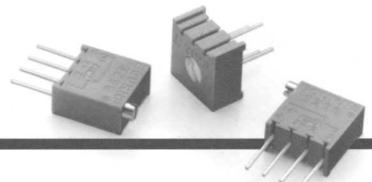
OP AMP OFFSET TRIMPOT® POTENTIOMETERS

for Operational Amplifier Circuit Applications

BOURNS TRIMPOT

New! CUSTOMER REQUESTED DESIGN

APPLICATION SYNOPSIS



The Bourns Offset Trimpot® Potentiometer is a unique device designed to significantly reduce the average offset voltage error in Operational Amplifier circuit applications.

ENTER A UNIQUE, NEW DESIGN BASED ON CUSTOMER REQUESTS!!

The Bourns Offset Trimpot® Potentiometer has been designed specifically for offset trim applications to reduce the sensitivity of the offset trim network to both power supply and temperature variation. As fringe benefits, the new design largely eliminates the elaborate trimming circuits (Fig. 5c and 5d). Therefore, you can also realize a savings in component count, board space and installation labor.

Power Supply Sensitivity

A reduction in power supply sensitivity with the Bourns Offset Trimpot® Potentiometer is accomplished by simply providing a tap at the center of the element, as shown in the schematic of the Bourns type OT1 in Figure 2.

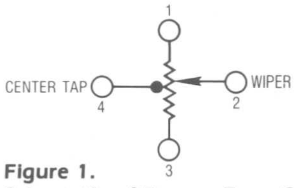
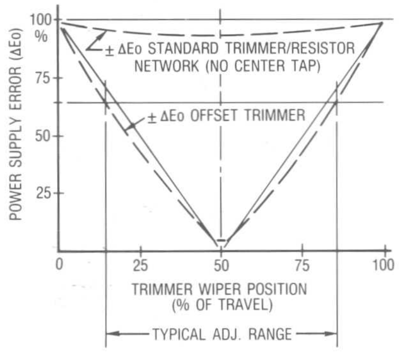


Figure 1. Schematic of Bourns Type OT1 Offset Trimpot® Potentiometer

The addition of this center-tap has two major effects:

- It creates a path through the Trimpot® Potentiometer element from both power supplies to ground, or common. This effectively isolates one of the supplies from having any effect on the offset adjustment voltage, depending on which side of the center-tap the wiper of the Trimpot® Potentiometer is located.
- Any variations in the power supply voltage on the side of the Trimpot® Potentiometer element that is active are reduced by a value that is a function of a divider ratio that is dependent on the position of the wiper on the element. The percentage of power supply variation appearing in the offset adjustment voltage will vary from zero at the null wiper setting to 100% at either full lock position. A practical design will dictate that the wiper is virtually never adjusted to either full lock position. There is always, therefore, a significant improvement in power supply sensitivity characteristics, as illustrated graphically in Figure 2.



Conclusion: The typical error resulting from power supply variation will be reduced by over 50% using a center-tapped potentiometer to replace those shown in Fig. 5. See Fig. 1.

Figure 2. Effect of Power Supply Variations on Offset Voltage

OP AMP PRIMER

Operational amplifiers are among the most versatile IC devices in use today. To perform useful functions, the user must make some additional external connections to the device. This entails adding a "feedback loop" to the op-amp. The manner in which the feedback is applied controls the overall gain and other operating characteristics of the complete amplifier.

Although op-amp manufacturers take great pains to minimize errors or distortions in the signal as it is processed, op-amps, like most other electronic components, are not perfect. As a result, several small errors normally appear in the output signal of the op-amp. By "error" we mean that the output signal contains something that was not a part of the input signal. While op-amps have many small errors in the output, the one we're most interested in here is "input offset voltage," or "offset voltage" for short.

Although the input offset voltage occurs due to errors within the op-amp, and is measured at the output, it is always referenced to the input of the op-amp.

Input offset voltage is the amount of voltage that would have to be applied between the input terminals of an op-amp to bring the output voltage to zero.

The effect of input offset voltage causes a shift in the d.c. level of the output signal, as illustrated in Figure 3. In Figure 3(a), we show an electrical input signal with a one volt peak amplitude that varies equally above and below a zero voltage level. If we apply this signal to an operational amplifier operating in a non-inverting mode with a gain of ten, and the op-amp has a positive offset voltage of 5 millivolts (.005 volts), then the signal at the output of the circuit will appear as shown in Figure 3(b). You can see that the entire waveform is no longer symmetrical about the zero voltage line, but is "offset" in the positive direction by the amount of the offset voltage multiplied by the gain of the amplifier circuit (.005 X 10).

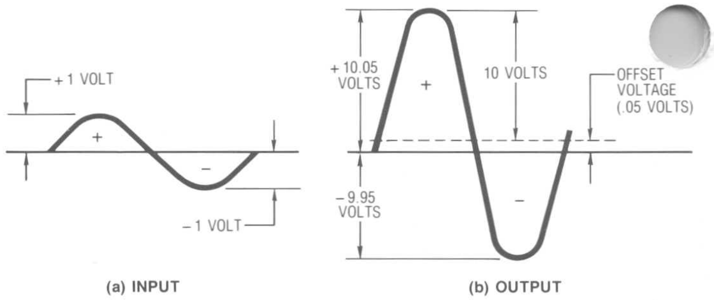


Figure 3. Effects of Op-Amp Input Offset Voltage on Signal

You can see that the amount of error in the signal at the output of an op-amp depends on two factors: (1) the inherent input offset voltage of the op-amp, and (2) the amount of gain applied to the input signal by the op-amp.

The typical input offset voltage of an op-amp will range from a few microvolts to several millivolts depending on the design level of the op-amp. If a given op-amp has an input offset voltage of 2 millivolts (.002 volts) and the circuit gain is set to 500 by the external circuitry, then the output signal will contain an error of 1 volt (.002 X 500). Even though the input offset voltage is typically a very small value, it can result in relatively large errors in the output signal if significant gain is used in the circuit. Be aware that offset voltage errors are cumulative in DC coupled circuits. If we have several op-amps connected in series, that is, the output of one op-amp feeding into the input of another op-amp, any offset errors will accumulate and be multiplied by the gain of any following stages.

Provisions are often made by the op-amp manufacturer for trimming the input offset voltage of the op-amp through the use of an externally connected trimmer potentiometer, as shown in Figure 4. In most cases, however, the manufacturer indicates that the addition of this trimmer will result in some degradation of the input voltage drift with temperature.

The resistance value of this trimmer is usually specified by the op-amp manufacturer to minimize offset voltage drift with temperature and to provide the desired range of adjustment and resolution.

Many op-amps, however, do not include provisions for trimming the input offset voltage, particularly those that are packaged in multiple form (i.e., several op-amps included in a single package).

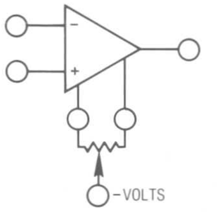


Figure 4. Op-Amp With Provisions for Offset Voltage Trim

Also, it is sometimes undesirable to trim the input offset voltage using the connections provided by the manufacturer because of the possible increase in offset voltage drift, mentioned earlier. The amount of drift in offset voltage with temperature that is induced by the attachment of a trimming potentiometer to the offset trim terminals of an op-amp varies considerably with the particular op-amp design. The drift for an input transistor pair is about 3 microvolts per degree Centigrade for each millivolt of offset adjustment.

So far, we have only talked about offset voltage errors that result from imperfections in the operational amplifier. There are often offset errors in the output of an op-amp circuit that result from other causes, the most common of which is probably imperfect grounding of the circuit. Stray currents flowing through common ground paths can result in the development of voltages not considered in the design of the circuit. These voltage drops are often large enough to cause offset errors that are much greater than the offset errors of the op-amp itself. The range of offset adjustment provided by the op-amp is often not great enough to compensate for these other external offset errors, so the designer may have to provide an external offset adjustment to handle them. Many instrumentation transducers have inherent offsets that the system designer must consider.

Input Offset Voltage Trimming

In some cases it is impossible or undesirable to trim input offset voltage using manufacturer provided terminals. Other external circuits have been developed to compensate for the input offset voltage without the use of op-amp offset adjust terminals. The more common circuits used for this purpose are shown in Figure 5.

The objective of all of the offset trimming circuits shown in Figure 5 is to apply a voltage to the input of the op-amp that is equal and opposite in magnitude to the input offset voltage in order to reduce the output voltage to zero when the input signal is zero. The offset voltage may either be positive or negative with respect to ground, so the compensating voltage provided by the trimming network must also be adjustable over a positive to negative range that is great enough to include the highest offset voltage that may be encountered. Since regulated positive and negative power supplies are normally available to provide power to the op-amp, practical considerations dictate that these supplies also be used to derive the offset trimming voltage. The simplest way of doing this is to connect a trimming potentiometer from the positive to the negative power supply, as shown in Figure 5(a). This will allow the voltage at the wiper of the trimming potentiometer to be continuously adjusted to any value between the two supply voltages. However, since the power supply voltages are usually much larger than the required offset trimming voltage, it is difficult, even with the highest resolution trimming potentiometers, to set and hold a very small offset compensating voltage. Most applications,

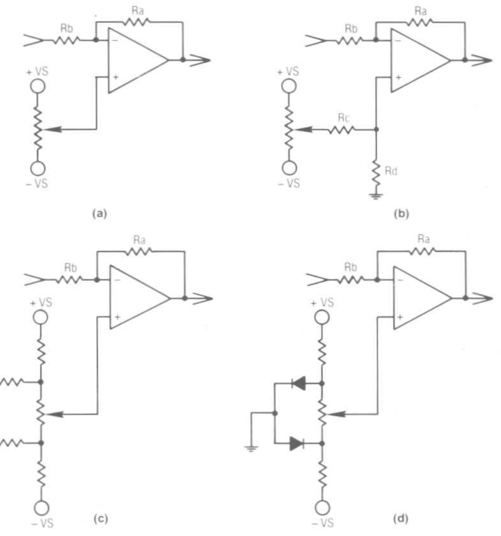


Figure 5. Input Offset Trimming Circuits

therefore, use some form of voltage-divider arrangement as shown in Figures 5(b) to 5(d). Figure 5(b), for example, adds a voltage-divider to the output (wiper) of the trimming potentiometer to reduce the adjustment range and increase the resolution to an appropriate level.

The increasing degree of complexity of the various offset trim circuits shown in Figure 5 reflect the efforts of designers to provide a more stable offset trim reference voltage. They all, to a greater or lesser degree depending on the circuit, have two main disadvantages:

1. **Power Supply Sensitivity.** Since the trimming network is floating across the positive and negative power supplies, any changes in voltage of either of the power supplies will cause a change in the output of the voltage divider network and, therefore, the output of the op-amp.

For example, if both of the power supply voltages were nominally ± 15 volts, the trimmer was set to the midpoint of its adjustment range, and the divider network was set to a ratio of 1000:1 as in Figure 5(b), then a drift of 1.0% (150 millivolts) of both supplies in the positive direction would result in a change of 150 microvolts (.000150 volts) in the offset adjustment voltage at the output of the trim network. The trim network output is an input to the op-amp. This error voltage is amplified by the amount of gain set by the external feedback circuit and is reflected in the output voltage. For a gain of 1000, the error at the output of the op-amp would be 150 millivolts (1000 X .000150). For a typical output range of +/- 10 volts, this would be an error of 1.5%.

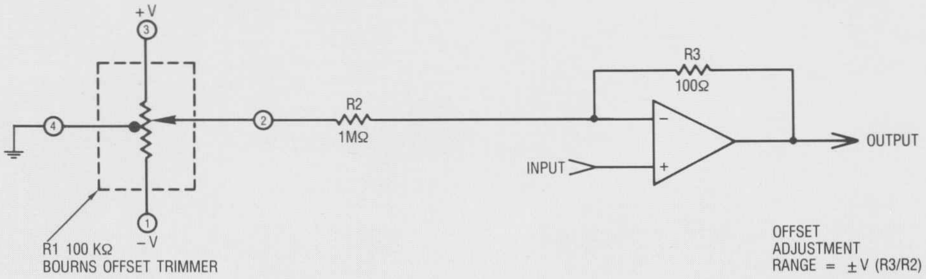
2. **Temperature Drift.** The resistive components making up the offset trimming network all have a resistance temperature coefficient that will cause their value to change slightly with changes in operating temperature. Unless very high quality components (i.e., those having low temperature coefficients) are used in the trimming network, the offset adjustment voltage may drift excessively with temperature changes.

As an example, if the voltage-divider output of the trimming potentiometer in Figure 5(b) had a temperature coefficient of 50ppm/C and the two divider resistors, Rc and Rd were typical carbon film resistors with a worst case opposing T.C. of 300ppm/°C, the output of the trimming network could change over 6% if the temperature changed 100 degrees Centigrade. As in the previous example, this error is also amplified by the op-amp according to the value of gain setting resistors selected.

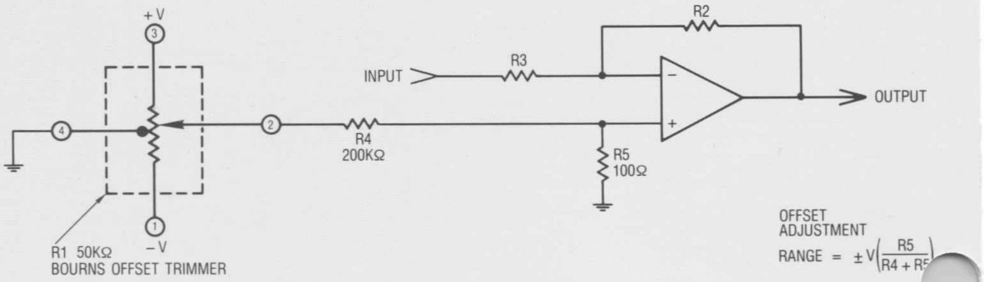
SUGGESTED OFFSET VOLTAGE ADJUSTMENT CIRCUITS

BOURNS

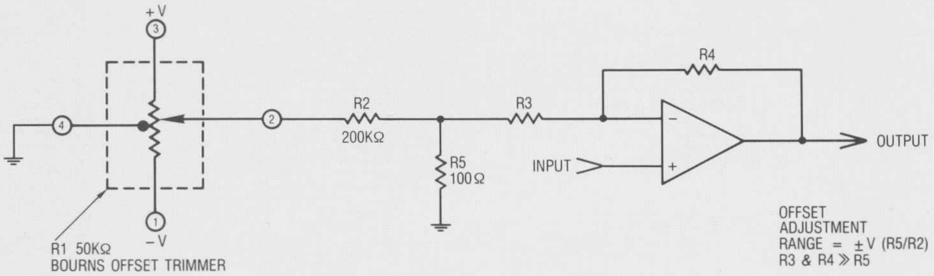
Voltage Follower



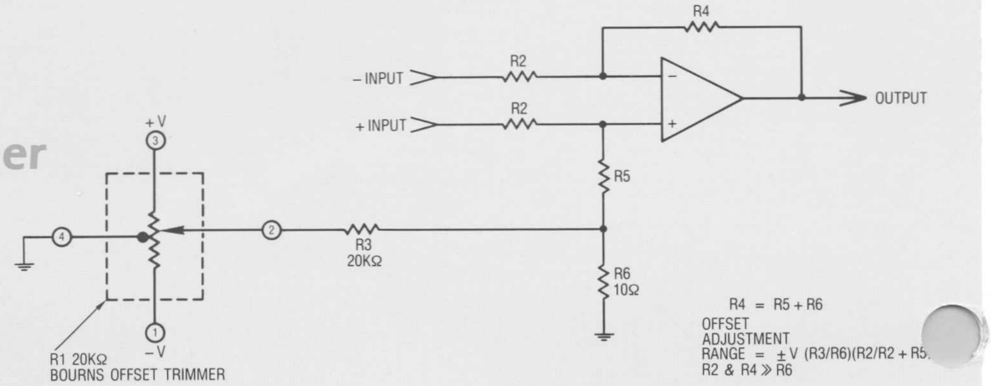
Inverting Amplifier



Non-Inverting Amplifier



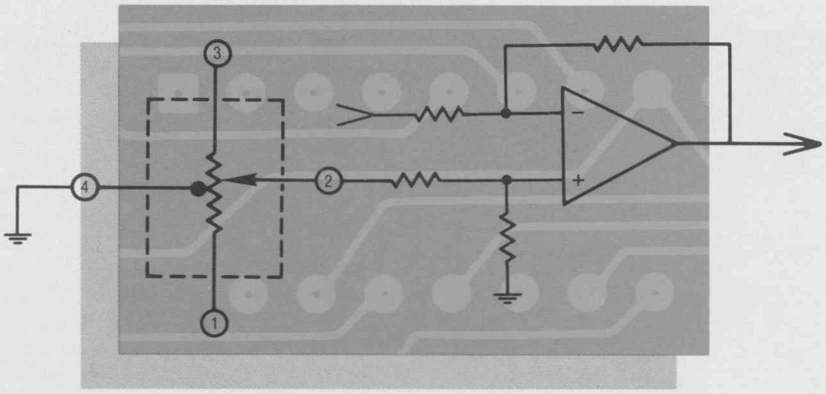
Differential Amplifier



OP AMP OFFSET ADJUST TRIMPOT® POTENTIOMETERS

New!

The New Selection of Offset Trimpot® Potentiometers from Bourns Provides Solutions to Compound Design Concerns. Unique Design Based on Customer Requests!



Imagine improving your performance in operational amplifier circuit applications while you reduce assembly operations and assembly costs!

BETTER PERFORMANCE
Offset voltage error is greatly reduced due to output variation in power supply voltages.

ASSEMBLY REDUCTIONS
Assembly operation is easier due to simple pin design which minimizes board drilling.

MINIMIZED CIRCUIT COMPLEXITY
Replaces conventional offset trim networks. Provides the same range of adjustment as typical discrete component networks.

IMPROVED POWER SUPPLY SENSITIVITY
Special center tapped element reduces power supply sensitivity by isolating the supplies, minimizing the effects of supply drift on the offset adjustment voltage.

ENHANCED RELIABILITY
Unique seal, high temperature materials and construction allow compatibility to virtually all cleaning solvents and harsh assembly environments without component damage.

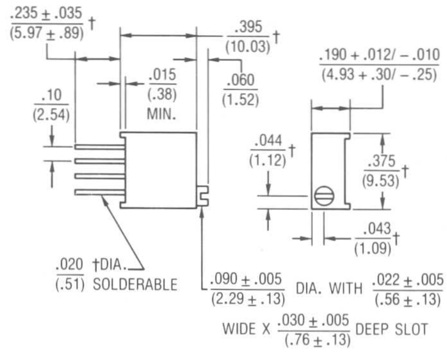
MAXIMUM DESIGN FLEXIBILITY
Available in multiturn and single-turn styles, in an assortment of standard resistance ranges.

COST REDUCTIONS
Unique characteristics reduce board space and component count for smaller, more cost-effective products.

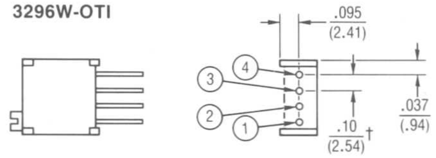
<table>
<tr><th></th><th>3296-OT1</th><th>3386-OT1</th></tr>
<tr><td colspan="3">Electrical Characteristics</td></tr>
<tr><td>Standard Resistance Range (Pin 1 to Pin 3)
(See Standard Resistance Table)</td><td colspan="2">100 ohms to 1 megohm</td></tr>
<tr><td>Resistance Tolerance</td><td colspan="2">±20% std.</td></tr>
<tr><td>Minimum Resistance</td><td colspan="2">2 ohms max.</td></tr>
<tr><td>Voltage Output Variation</td><td colspan="2">±0.25%</td></tr>
<tr><td>Adjustability (VR)</td><td colspan="2">±0.01%</td></tr>
<tr><td>Insulation Resistance @ 500 VDC</td><td colspan="2">100 megohms min.</td></tr>
<tr><td>Dielectric Strength</td><td colspan="2"></td></tr>
<tr><td>Sea Level</td><td colspan="2">900 VAC</td></tr>
<tr><td>70,000 Feet</td><td colspan="2">350 VAC</td></tr>
<tr><td>Effective Electrical Travel, Nom.</td><td>25 Turns</td><td>280° nom.</td></tr>
<tr><td>Center Tap Resistance</td><td colspan="2">2 ohms max.</td></tr>
<tr><td>Center Tap Electrical Center</td><td colspan="2">±5%</td></tr>
<tr><td>Center Tap Dead Band</td><td>0.5 turn</td><td>6°±4°</td></tr>
<tr><td colspan="3">Environmental Characteristics</td></tr>
<tr><td>Power Rating</td><td colspan="2"></td></tr>
<tr><td>70°C</td><td colspan="2">0.25 watt</td></tr>
<tr><td>125°C</td><td colspan="2">0 watt</td></tr>
<tr><td>Temperature Range</td><td colspan="2">−55°C to +125°C</td></tr>
<tr><td>Temperature Stability (ΔVR)</td><td colspan="2">±0.5% max.</td></tr>
<tr><td>Seal Test</td><td colspan="2">85°C Fluorinert*</td></tr>
<tr><td>Humidity, MIL-STD-202, Method 103
96 Hours</td><td colspan="2">±2% ΔTR IR
10 megohms min.</td></tr>
<tr><td>Vibration, 20G</td><td colspan="2">±1% ΔTR</td></tr>
<tr><td>Shock, 100G</td><td colspan="2">±1% ΔTR</td></tr>
<tr><td>Load Life, 1,000 Hours 0.25 watts at 70°C</td><td colspan="2">±3% ΔTR</td></tr>
<tr><td>Mechanical Life, 200 Cycles</td><td colspan="2">±4% ΔTR</td></tr>
<tr><td colspan="3">Physical Characteristics</td></tr>
<tr><td>Torque</td><td colspan="2">3.0 oz-in. max.</td></tr>
<tr><td>Mechanical Stops</td><td>Wiper idles</td><td>Solid</td></tr>
<tr><td>Terminals</td><td colspan="2">Solderable pins</td></tr>
<tr><td>Weight</td><td colspan="2">0.03 oz.</td></tr>
<tr><td>Marking</td><td colspan="2">Manufacturer's name, resistance code, etc.</td></tr>
</table>

*"Fluorinert" is a registered trademark of 3M Co.

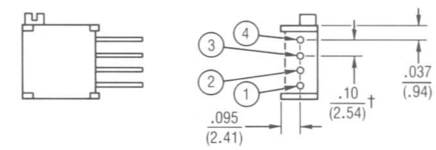
3296-OT1



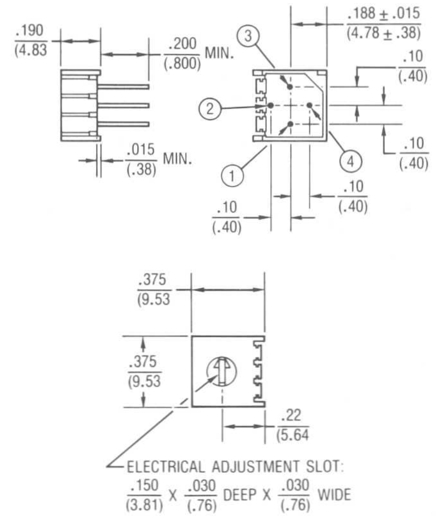
3296W-OTI

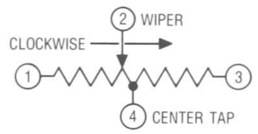


3296X-OTI



3386P-OT1





TOLERANCES: ± .010 / (.25) OR LESS EXCEPT WHERE NOTED

DIMENSIONS: IN. / (MM)

STANDARD RESISTANCE TABLE

Resistance (Ohms)	Resistance Code
100	101
200	201
500	501
1,000	102
2,000	202
5,000	502
10,000	103•
20,000	203
50,000	503•
100,000	104•
200,000	204
500,000	504
1,000,000	105

•Preferred Values

Special resistances available.

HOW TO ORDER

3296 X — OT1 — 103

- Model — 3296
- Style — X
- Catalog Product — OT1
- Resistance Code — 103
  - First 2 significant digits of value
  - Third digit number of zeros

BOURNS TRIMPOT
1200 Columbia Avenue
Riverside, CA 92507
TEL (909) 781-5500
FAX 909 781-5700
www.bourns.com

Specifications are subject to change without notice.